FIG. 1

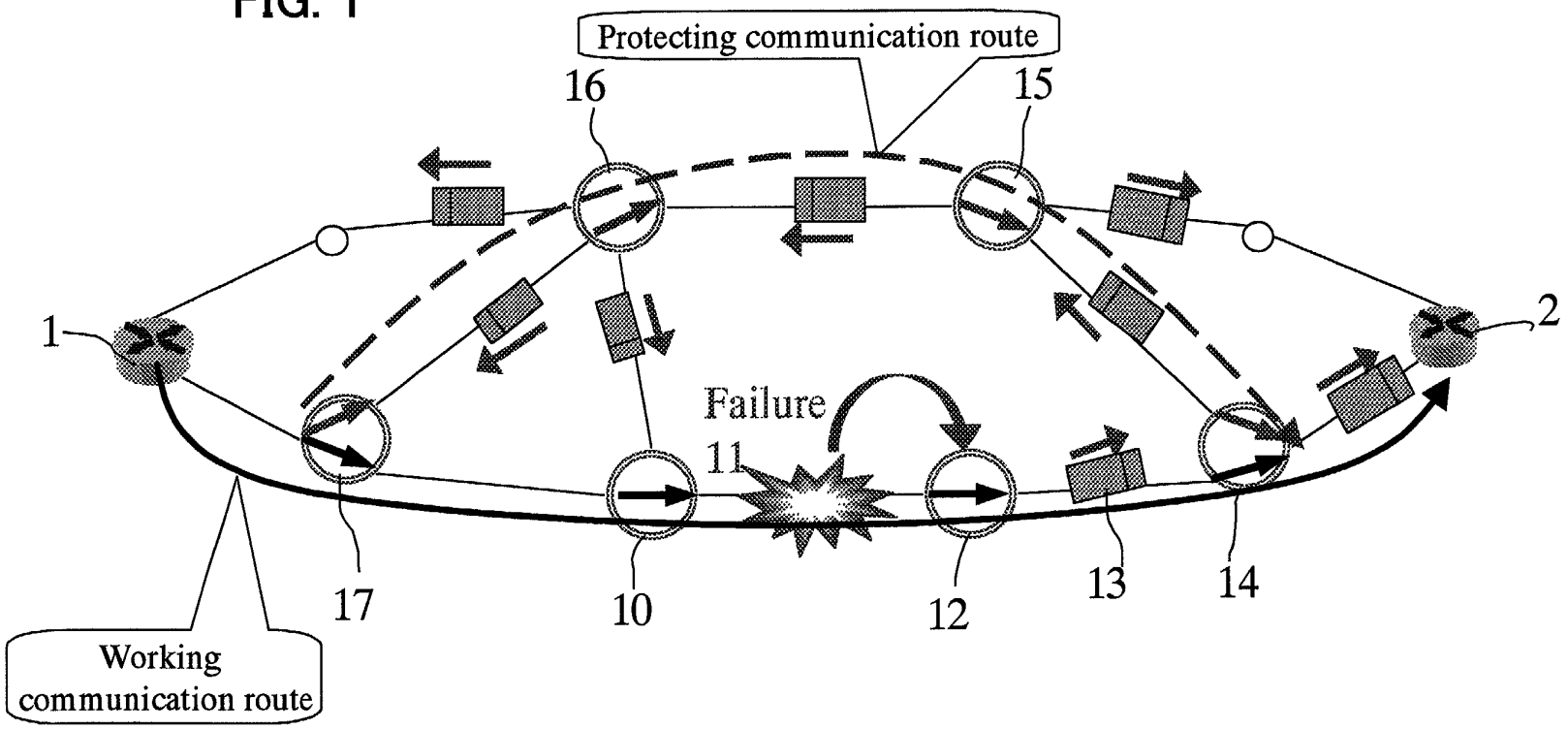
Protecting communication route
16
15
1
2
Failure
11
17
10
12
13
14
Working
communication route

FIG. 2

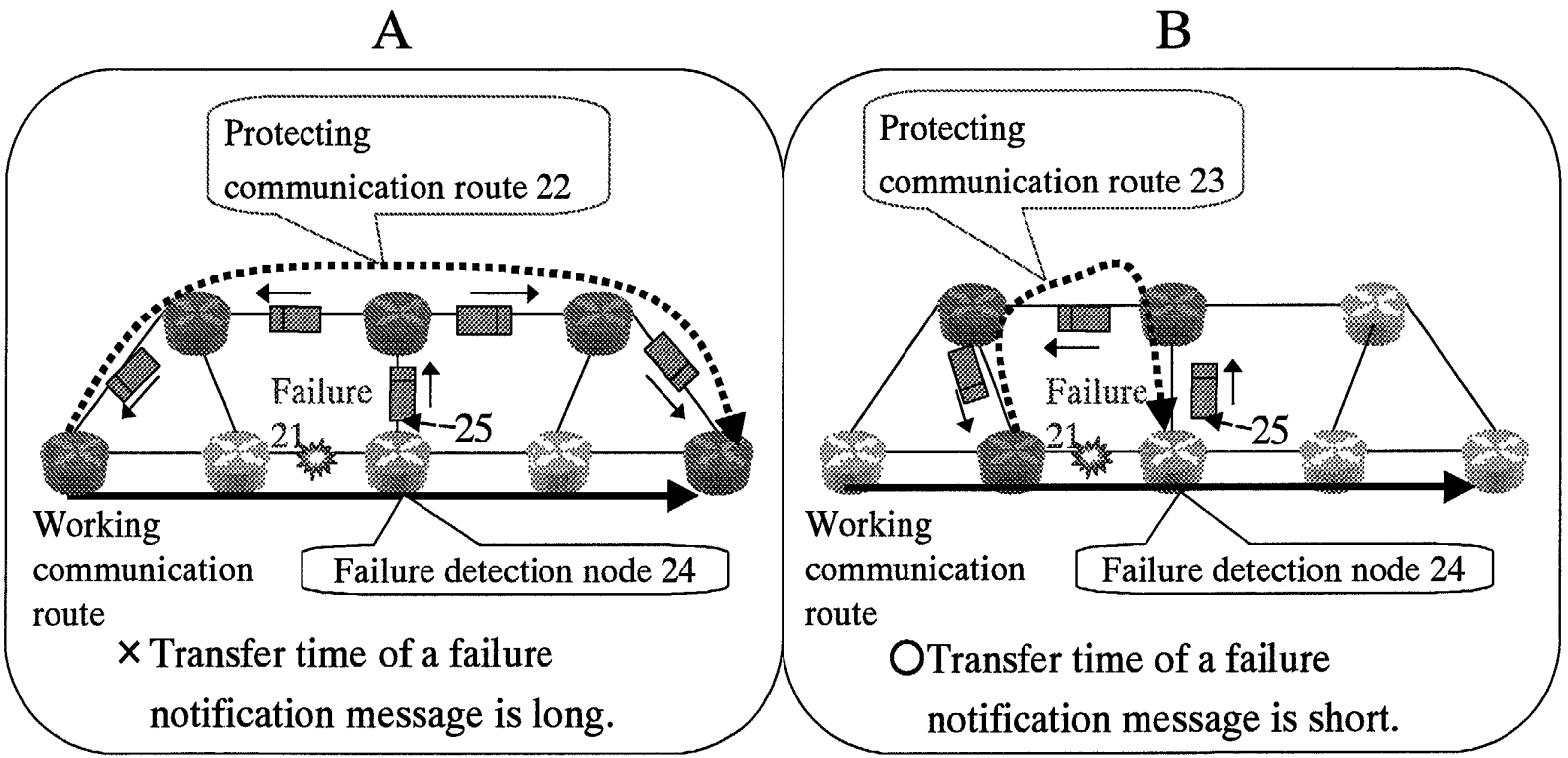
A
Protecting communication route 22
Failure 21
25
Working communication route
Failure detection node 24
× Transfer time of a failure notification message is long.
B
Protecting communication route 23
Failure 21
25
Working communication route
Failure detection node 24
○ Transfer time of a failure notification message is short.

FIG. 3

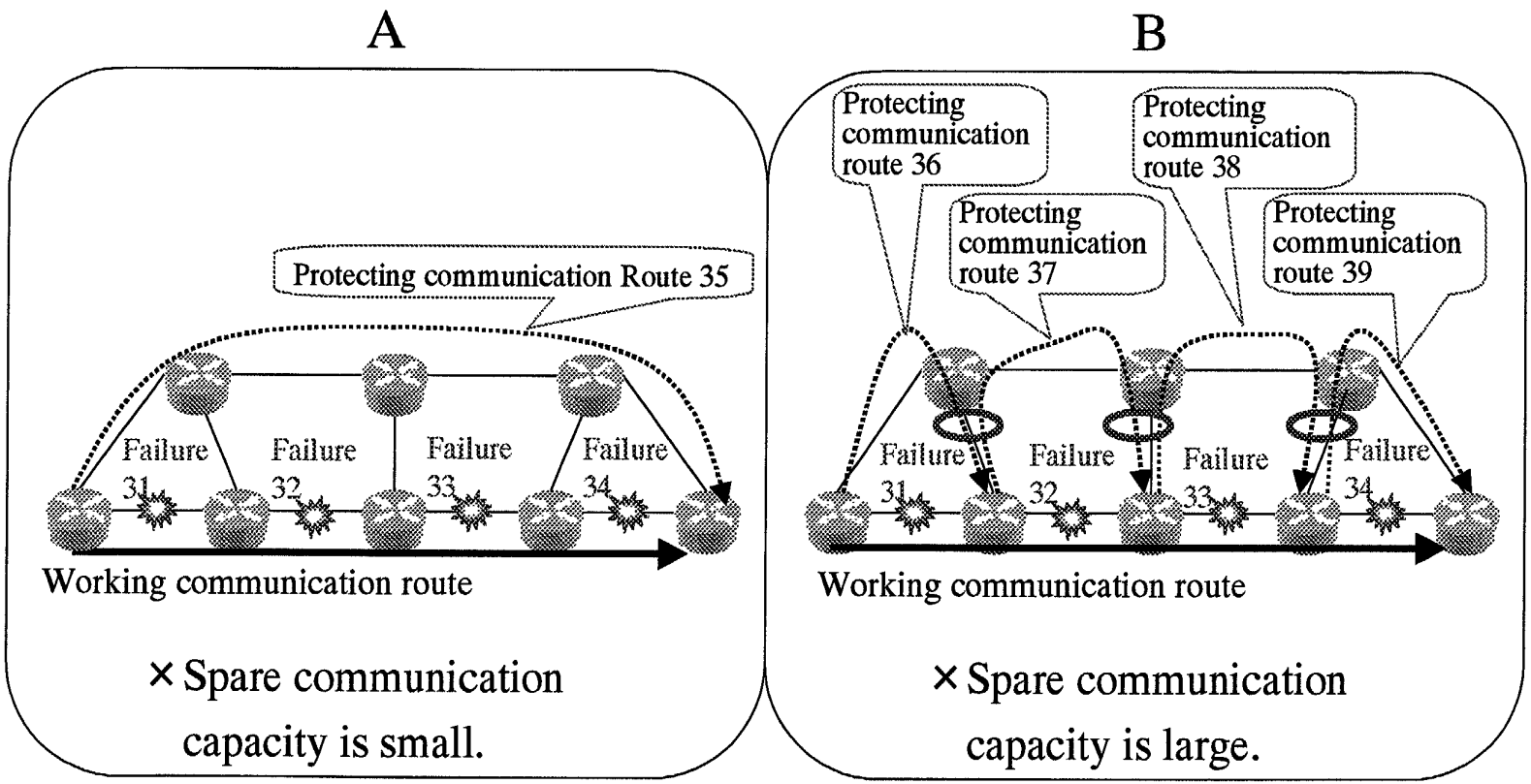
A
Protecting communication Route 35
Failure 31
Failure 32
Failure 33
Failure 34
Working communication route
× Spare communication capacity is small.
B
Protecting communication route 36
Protecting communication route 37
Protecting communication route 38
Protecting communication route 39
Failure 31
Failure 32
Failure 33
Failure 34
Working communication route
× Spare communication capacity is large.

FIG. 4

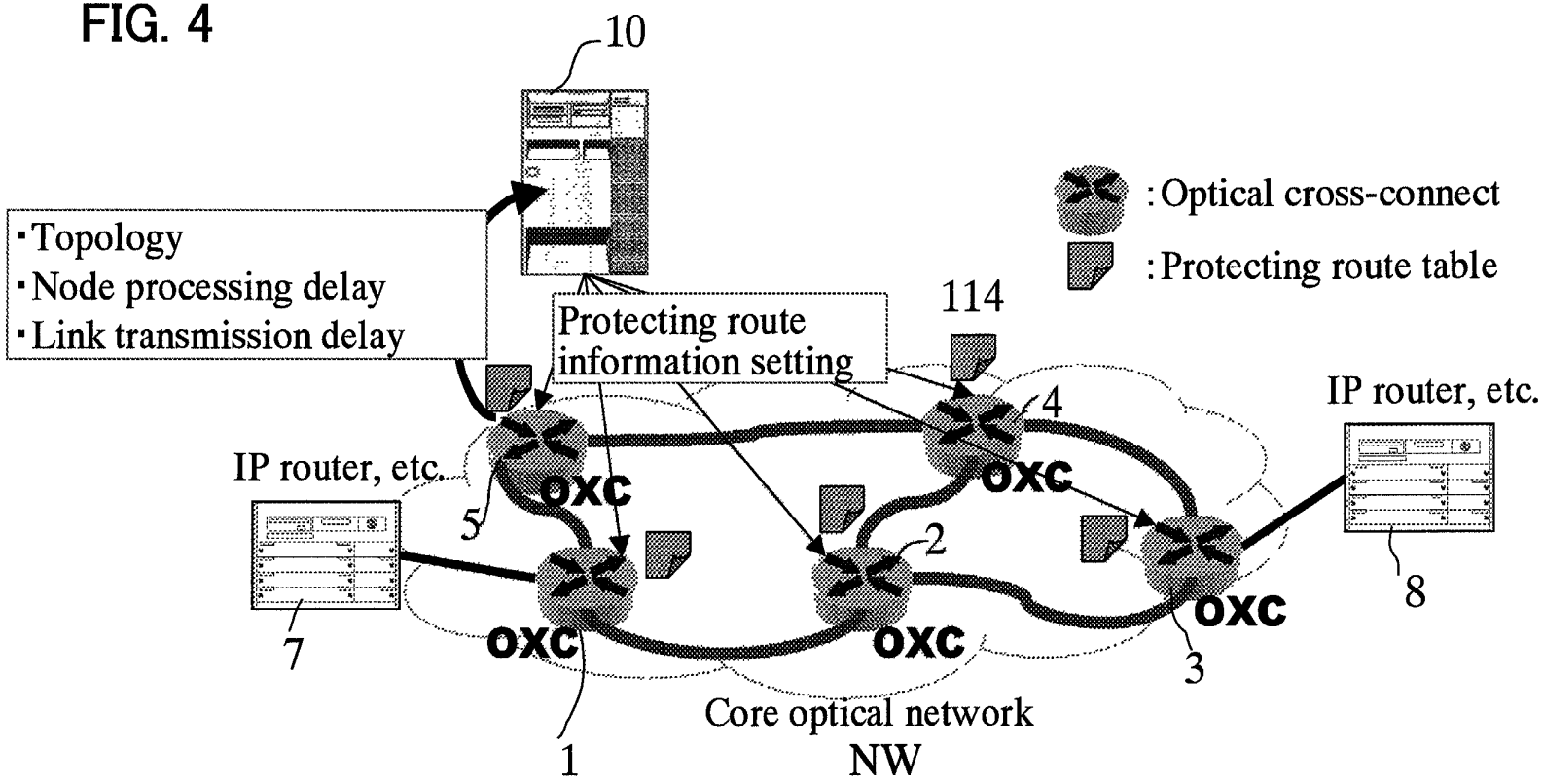
10
·Topology
·Node processing delay
·Link transmission delay
Protecting route information setting
: Optical cross-connect
: Protecting route table
114
4
IP router, etc.
IP router, etc.
OXC
OXC
5
2
OXC
OXC
OXC
7
8
3
1
Core optical network NW

FIG. 5

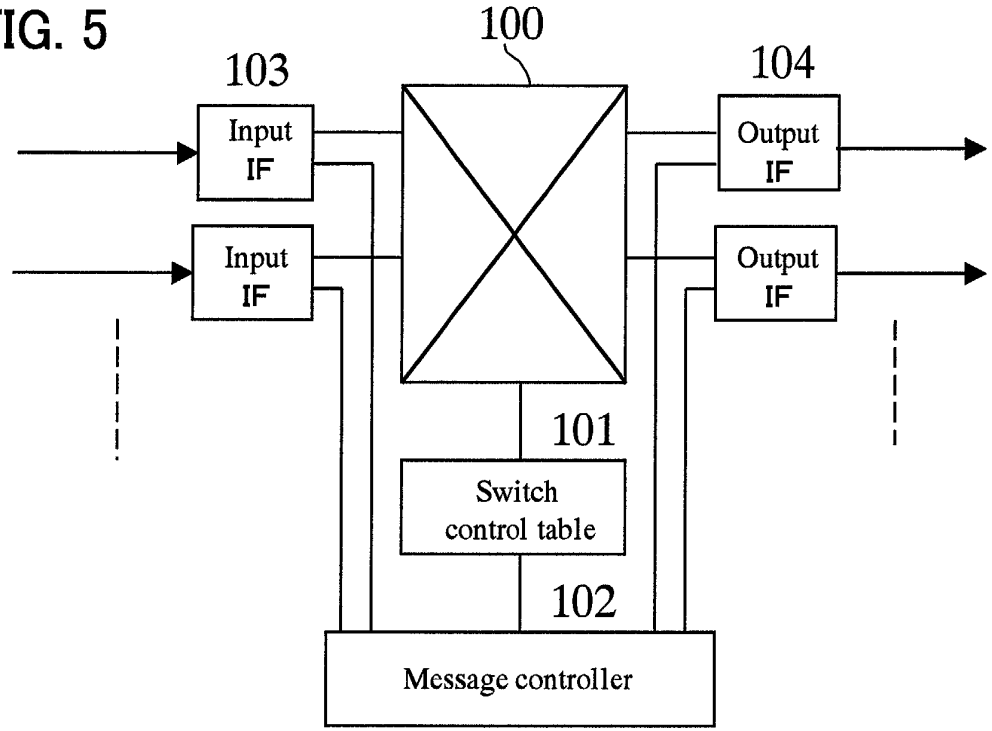
100
103
104
Input IF
Input IF
Output IF
Output IF
101
Switch control table
102
Message controller

FIG. 6

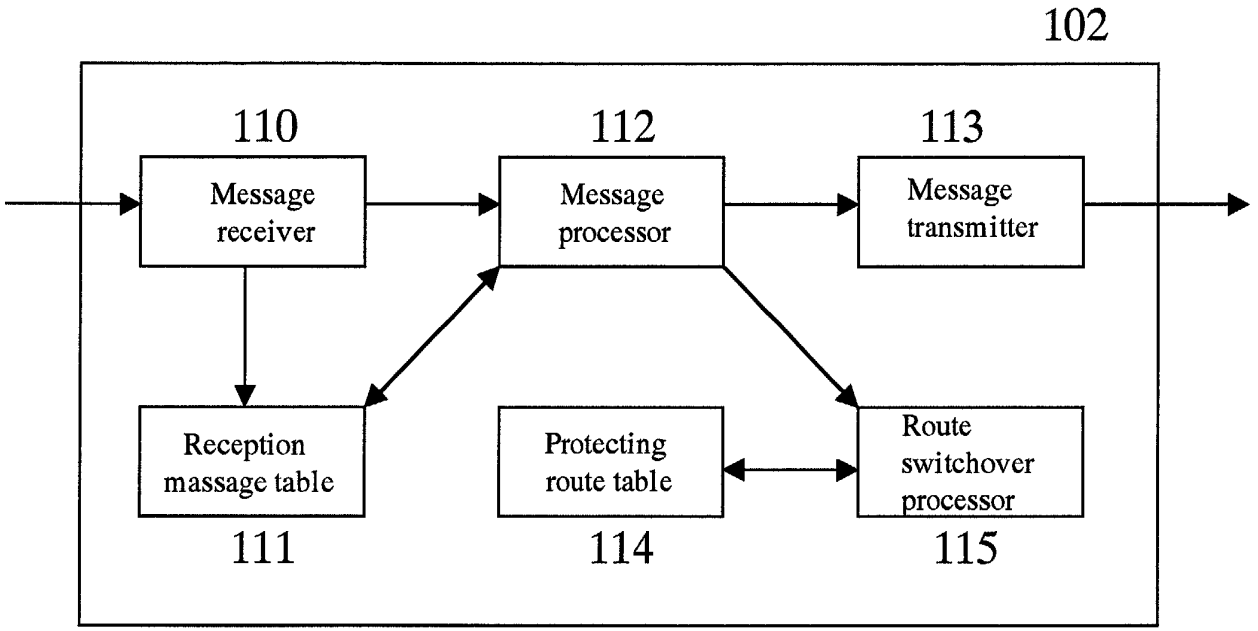
102
110
112
113
Message receiver
Message processor
Message transmitter
Reception massage table
Protecting route table
Route switchover processor
111
114
115

FIG. 7

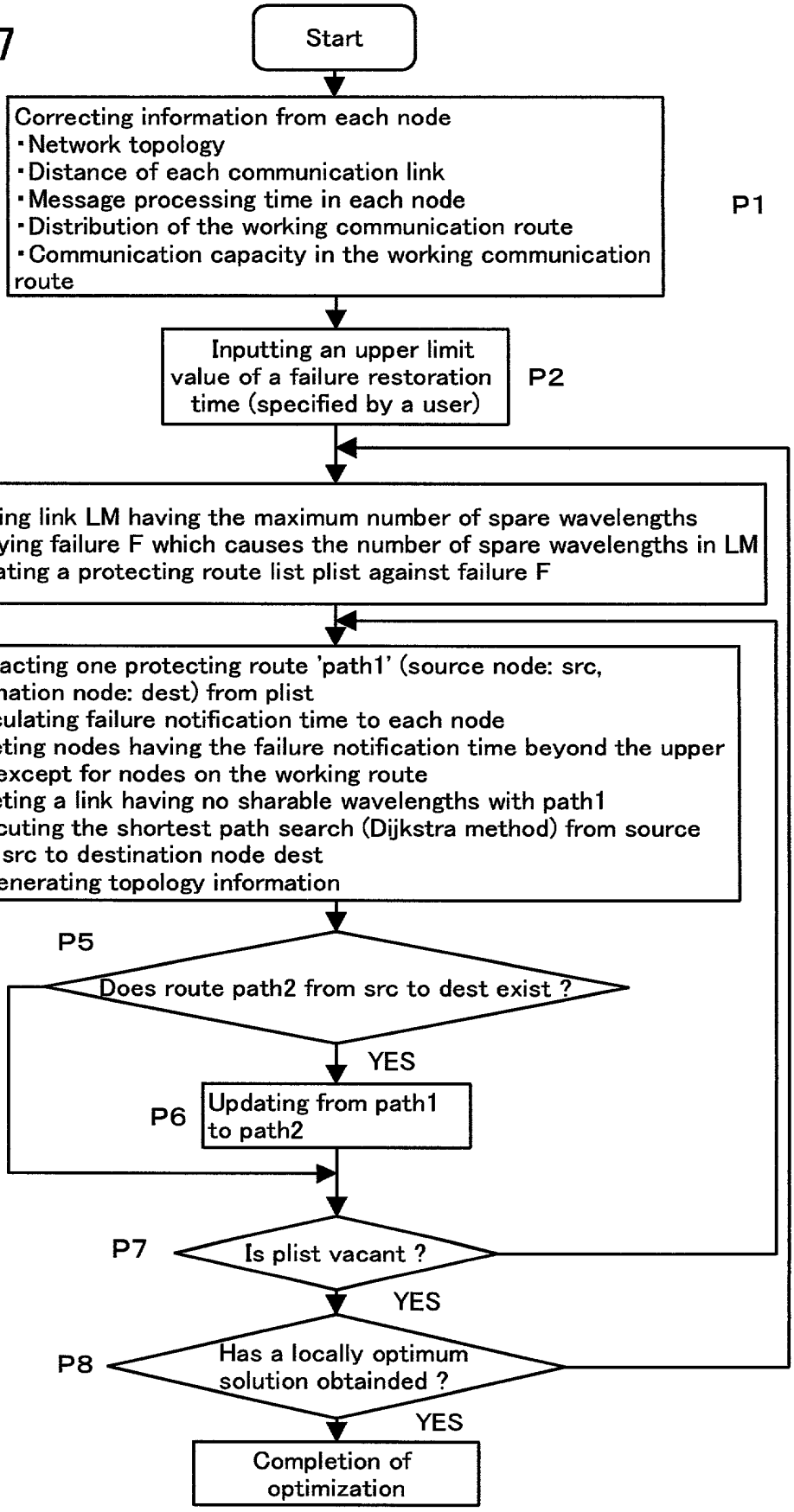
Start
Correcting information from each node
・Network topology
・Distance of each communication link
・Message processing time in each node
・Distribution of the working communication route
・Communication capacity in the working communication route
P1
Inputting an upper limit value of a failure restoration time (specified by a user)
P2
P3
・Selecting link LM having the maximum number of spare wavelengths
・Identifying failure F which causes the number of spare wavelengths in LM
・Generating a protecting route list plist against failure F
P4
・Extracting one protecting route 'path1' (source node: src, destination node: dest) from plist
・Calculating failure notification time to each node
・Deleting nodes having the failure notification time beyond the upper limit except for nodes on the working route
・Deleting a link having no sharable wavelengths with path1
・Executing the shortest path search (Dijkstra method) from source node src to destination node dest
・Regenerating topology information
P5
Does route path2 from src to dest exist ?
YES
P6
Updating from path1 to path2
P7
Is plist vacant ?
YES
P8
Has a locally optimum solution obtainded ?
YES
Completion of optimization

FIG. 8

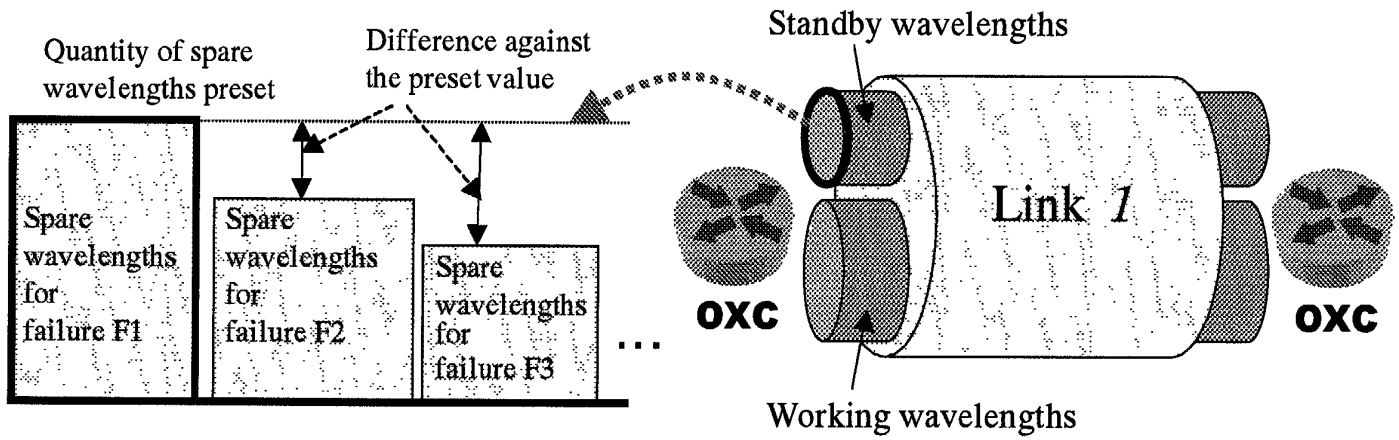
Quantity of spare wavelengths preset
Difference against the preset value
Standby wavelengths
Spare wavelengths for failure F1
Spare wavelengths for failure F2
Spare wavelengths for failure F3
...
OXC
Link 1
OXC
Working wavelengths

FIG. 9

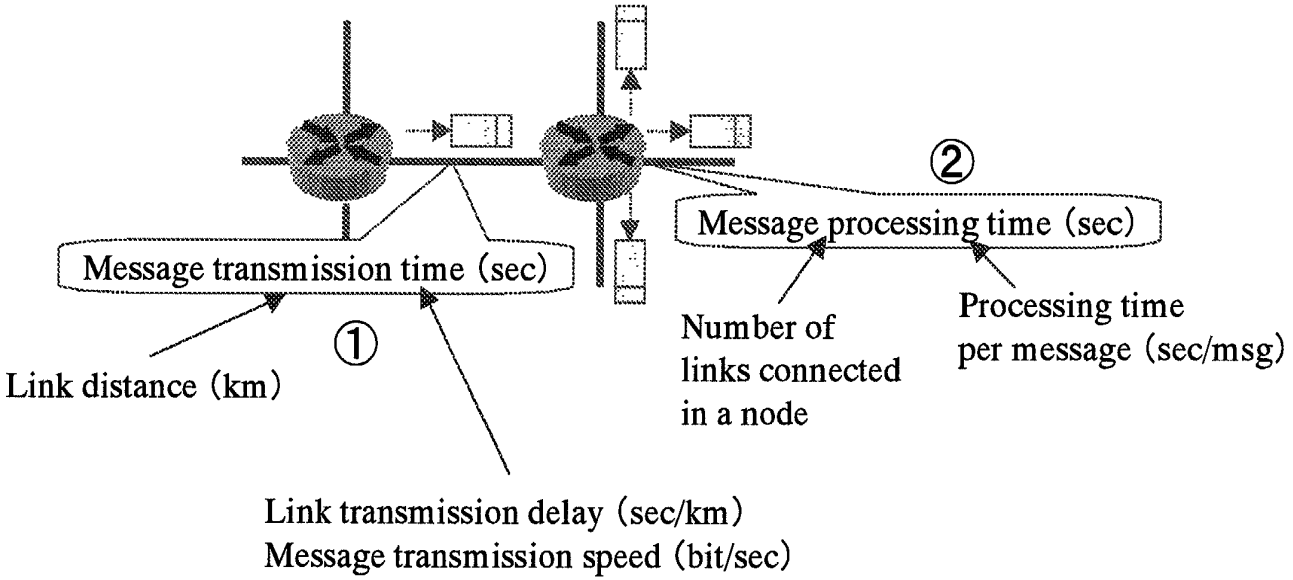
②
Message processing time (sec)
Message transmission time (sec)
①
Link distance (km)
Number of links connected in a node
Processing time per message (sec/msg)
Link transmission delay (sec/km)
Message transmission speed (bit/sec)

FIG. 10

Restoration time investigation table related to node 'N8'

Failure location 61	Failure detection node 62	Restoration time upper limit (ms) 63	Reception time of failure notification message (ms) 64	Route switchover time (ms) 65
Link L1 (N1,N4)	N1	50	8.75	41.25
	N4	50	4.50	45.50
Link L2 (N2,N5)	N2	50	3.25	46.75
	N5	50	10.0	40.00
Link L3	...	50	...	...

FIG. 11

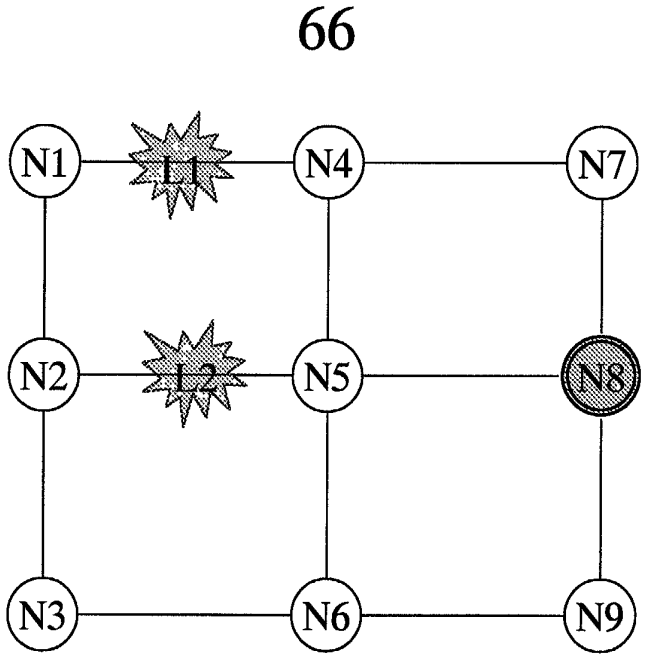

FIG. 12

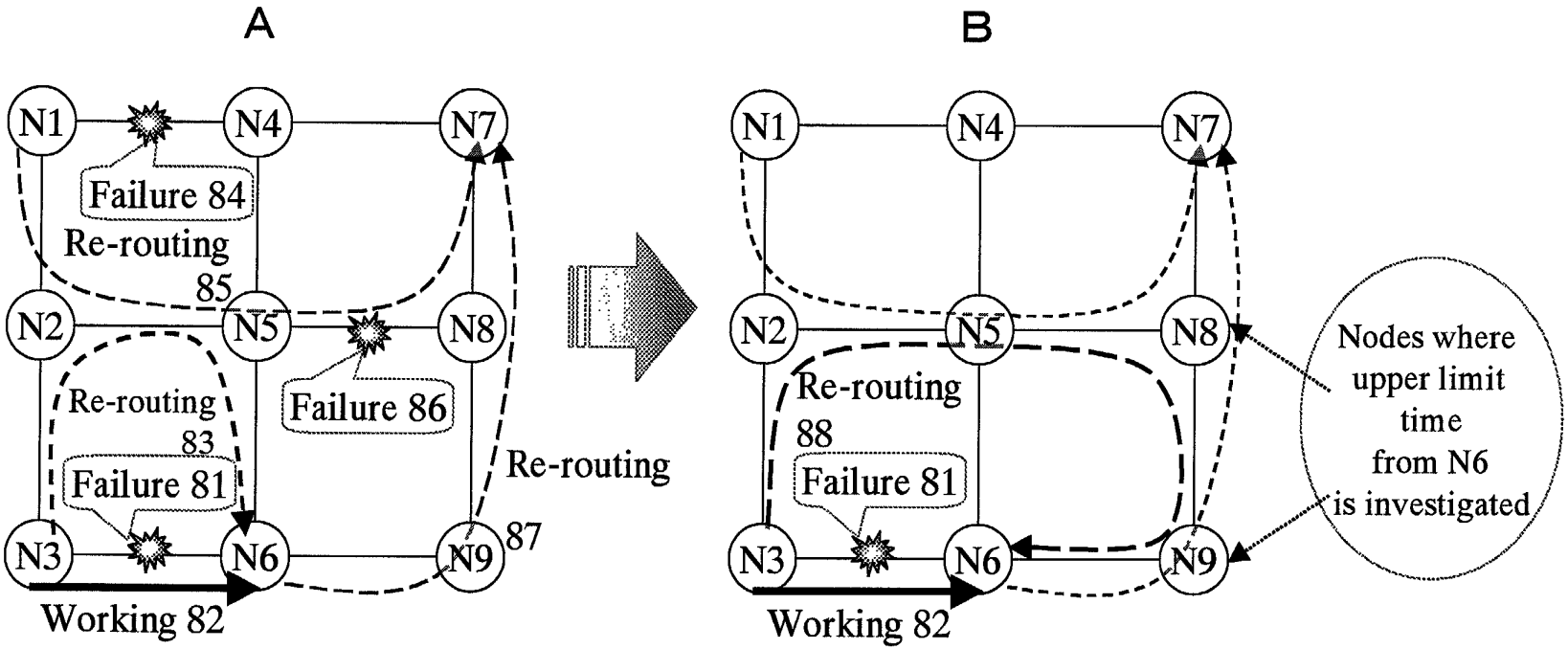
A
B
N1
N4
N7
N2
N5
N8
N3
N6
N9
Failure 84
Re-routing
85
Re-routing
83
Failure 81
Failure 86
Re-routing
87
Working 82
Re-routing
88
Failure 81
Working 82
Nodes where
upper limit
time
from N6
is investigated

FIG. 13

Protecting communication route information table

Failure location 71	Damaged transmission node 72	Damaged reception node 73	Protecting communication route 74
Link L1 (N1,N4)	N1	N4	Path141
	N4	N1	Path411, Path412
	N1	N7	Path171
	N2	N4	Path241, Path242,
	...	...	...
Link L2 (N2,N5)	N2	N5	Path251
	N5	N2	Path521, Path522
	...	...	...
Link L3 ...	...	...	...

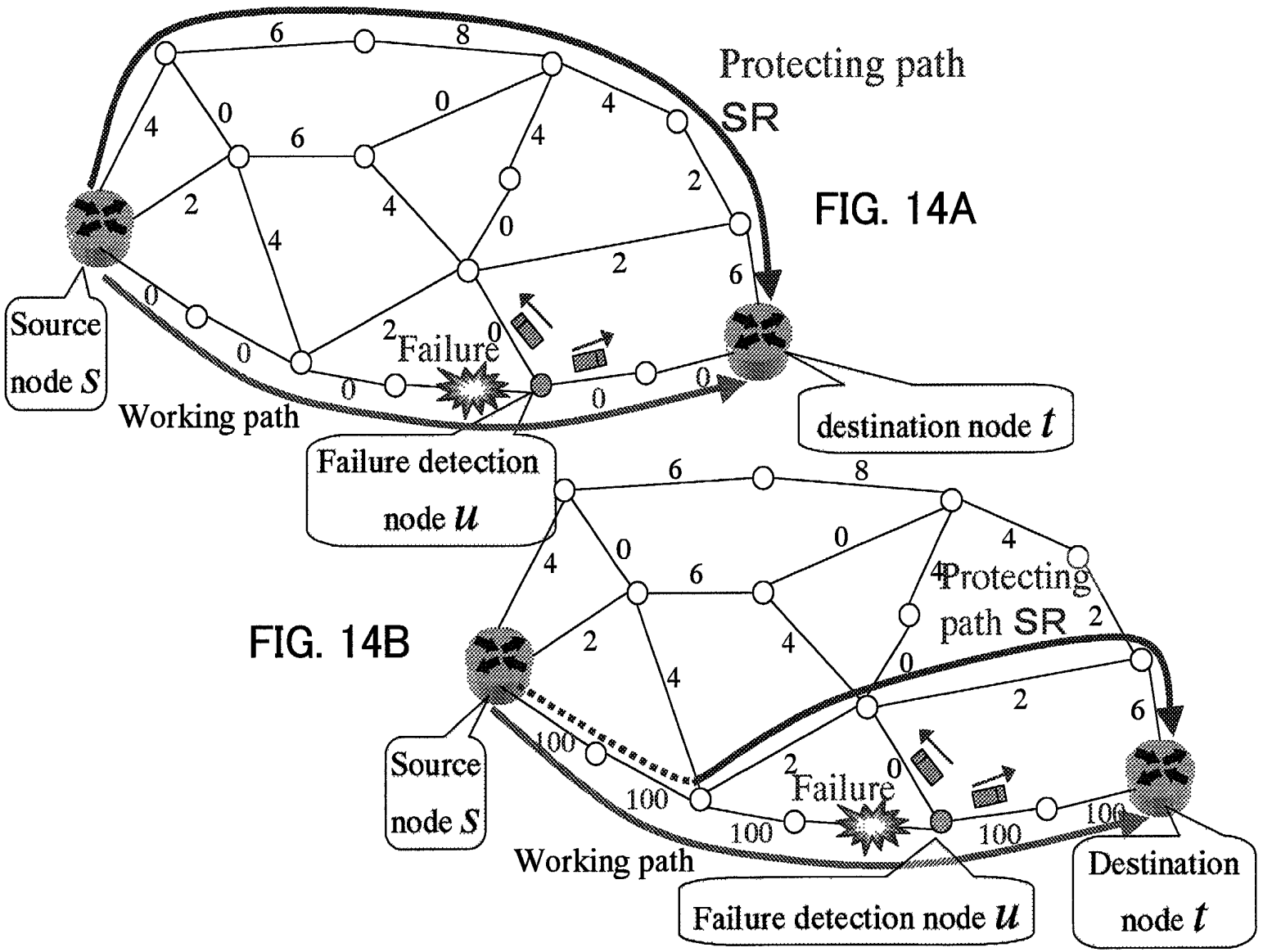

FIG. 14A

FIG. 14B

FIG. 15

Network scale	North America	Path length approx. 3000km
	Metropolitan area	Path length approx. 30km
Switchover system	Optical	Approx. 5.0e-3 sec
	Electric	Approx. 5.0e-9 sec
Message processing capability in a node (CPU capability)	'98	Approx. 1.0e-3 sec
	'01	Approx. 1.0e-4 sec

※Optical communication delay of 4.833e-6 sec/km is constantly fixed.

Fig. 16

		Network scale	
		North America (large)	Metropolitan area (small)
Switchover system	Optical		Communication delay neglected
	Electric	Switchover time neglected	

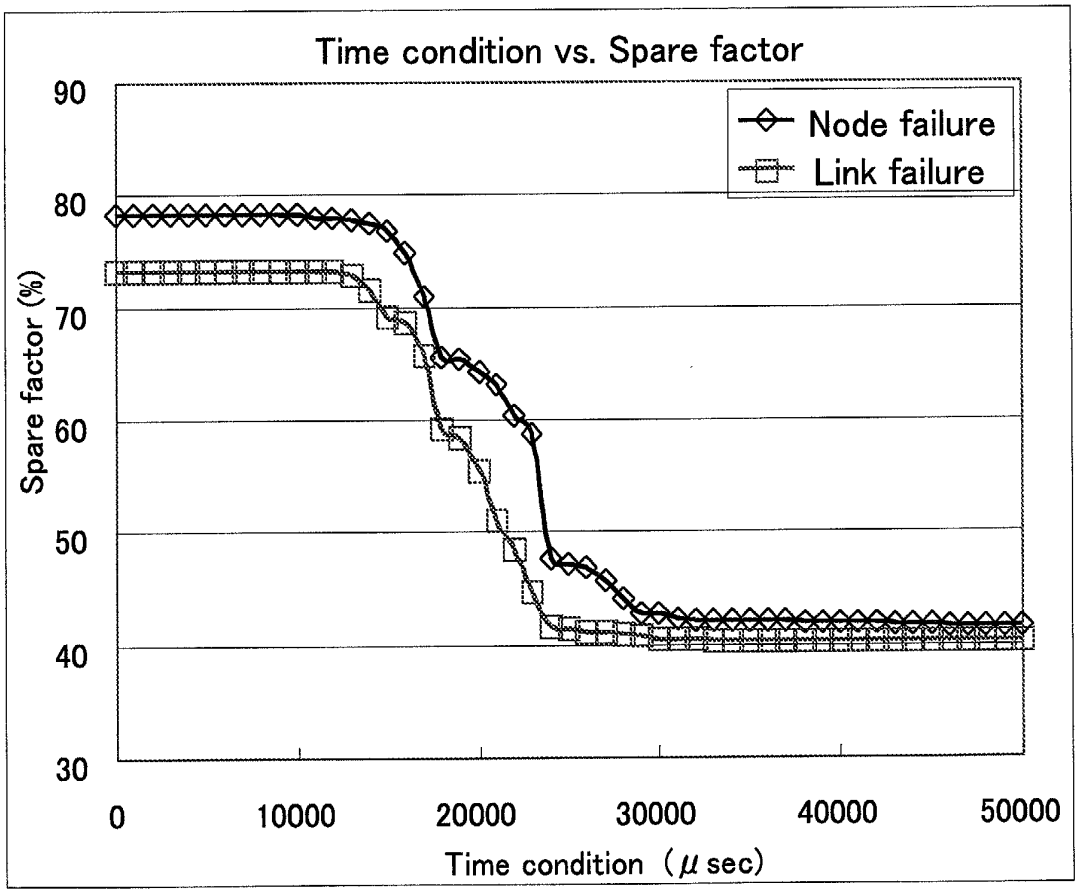
Time condition vs. Spare factor
Node failure
Link failure
Spare factor (%)
90
80
70
60
50
40
30
0
10000
20000
30000
40000
50000
Time condition (μ sec)

FIG. 18

	Spare factor	Average notification time	Maximum notification time
Time limit existent	41.5	18.767	24.7
Time limit non-existent	38.0	21.836	37.1